INDIANA DEPARTMENT OF TRANSPORTATION

INTER-DEPARTMENT COMMUNICATION

Standards Section – Room N642

Writer's Direct Line
232-6775

March 1, 2005

DESIGN MEMORANDUM No. 05-05
TECHNICAL ADVISORY

TO: **All Design, Operations, District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
Anthony L. Uremovich
Design Policy Engineer
Contracts and Construction Division

SUBJECT: **NCHRP *350* Bridge Railings and Transitions**

SUPERSEDES: **Design Memoranda 00-10 and 04-17 Technical Advisories**

EFFECTIVE: **Immediately**

I. Test Level Selection

The basic parameter for bridge-railing selection is the Test Level required at the site. This is a function of the following:

1. highway design speed;
2. average annual daily traffic and percent trucks;
3. bridge railing offset;
4. highway geometry (grades and horizontal curvature);
5. height of deck; and
6. type of land use below deck.

The detailed methodology for determining a bridge railing's Test Level is described herein. The methodology has been adapted from the AASHTO publication *Guide Specifications for Bridge Railings*. The performance-level designations in the *Guide Specifications* have been converted to the Test Level designations in National Cooperative Highway Research Program *Report 350*

(NCHRP *350*) *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. The *Guide Specifications* methodology is based on a benefit/cost analysis which considers occupant safety, vehicular types, highway conditions and costs. The overall objective is to match the bridge railing's Test Level (and therefore costs) to site needs.

The Performance Level (PL-__) terminology applies to the AASHTO *Guide Specifications for Bridge Railings*. Under the new NCHRP *350* criteria, performance of bridge railings and associated transitions is measured in terms of Test Levels (TL-__). A bridge-railing equivalency table for converting PL-1, PL-2 and PL-3 railings to TL-2, TL-4 and TL-5 railings is provided in Figure 05-05A, Bridge Railing Level Equivalency.

TESTING CRITERIA	**ACCEPTANCE EQUIVLENCIES**					
NCHRP *Report 350*	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
AASHTO *Guide Specifications for Bridge Railings*	---	PL-1	---	PL-2	PL-3	---

BRIDGE RAILING LEVEL EQUIVALENCY

Figure 05-05A

NCHRP *350* identifies six Test Levels. To limit the number of necessary bridge railings, Indiana has selected three of these Test Levels and has developed warrants for their use.

All english-units figures referenced below are attached hereto.

The Test Level is selected based on the following:

A. TL-2

A TL-2 bridge railing is appropriate on a bridge which meets the following:

1. the bridge is located on a route not on the State highway system, and the adjusted AADT in the construction year appears within the TL-2 range shown in *Indiana Design Manual* Figure 49-9D(50), 49-9D(60), 49-9D(70), 49-9D(80), or 49-9D(90), Median Barrier and Bridge Railing Test Level Selection, [english-units Figure 49-9D(30), 49-9D(40), 49-9D(45), 49-9D(50), or 49-9D(55)] for the appropriate design speed; or

2. the bridge is located on a State-highway-system route with a design speed of 70 km/h (45 mph) or lower and the adjusted AADT in the construction year appears within the TL-2 range shown in *Indiana Design Manual* Figure 49-9D(50), 49-9D(60), or 49-9D(70) [english-units Figure 49-9D(30), 49-9D(40), or 49-9D(45)], for the appropriate design speed.

B. TL-4

A TL-4 bridge railing is appropriate on every bridge which meets the following:

1. the criteria for TL-2 are not met; and

2. the adjusted AADT in the construction year appears within the TL-4 range shown in *Indiana Design Manual* Figure 49-9D(50), 49-9D(60), 49-9D(70), 49-9D(80), 49-9D(90), 49-9D(100), or 49-9D(110) [english-units Figure 49-9D(30), 49-9D(40), 49-9D(45), 49-9D(50), 49-9D(55), 49-9D(60), or 49-9D(65), attached hereto], for the appropriate design speed.

C. TL-5

A TL-5 bridge railing is appropriate on a bridge where the adjusted AADT in the construction year appears within the TL-5 range shown in *Indiana Design Manual* Figures 49-9D(50) through 49-9D(110) [english-units Figures 49-9D(30) through 49-9D(65)], whichever applies.

D. TL-6

A TL-6 bridge railing is intended to reduce to almost zero the probability that large van-type, semi-trailer trucks will penetrate the railing. The TL-6 bridge railing is intended to contain and redirect a tanker trailer truck, which has a very high point of contact with a bridge railing.

The decision to use a TL-6 bridge railing is a policy decision based on a site-by-site evaluation; therefore no numerical thresholds are provided. As an example, a TL-6 bridge railing may be selected on a highway with an extremely high volume of large trucks (or tanker trucks) where rollover or penetration beyond the barrier would result in severe consequences.

E. Making Test Level Determination

Test Level determination applies directly to level roadways on tangent, with bridge deck surfaces approximately 10.5 m (35 ft) above the under-structure ground or water surface, and with low-occupancy land use or shallow water under the structure. The traffic volume used to determine the Test Level is the construction year AADT.

For highway conditions that differ from those described above, the AADT should be adjusted by the correction factors shown in *Indiana Design Manual* (or english-units) Figure 49-9B, Grade Traffic Adjustment Factor (K_g) and Curvature Traffic Adjustment (Factor (K_c), and *Indiana Design Manual* (or english-units) Figure 49-9C, Traffic Adjustment Factor (K_s) (Deck Height and Under-Structure Shoulder Height Conditions). These correction factors are for highway grade (K_g), horizontal curvature (K_c), and deck/shoulder height and under-structure conditions (K_s). The high-occupancy land use referred to in Figure 49-9C applies to a site where there is a relatively high probability for injury or for loss of human life. The low-occupancy land use applies to a site where the probability for injury or loss of human life is relatively low.

Once the adjusted AADT is determined, the appropriate Test Level can be determined from *Indiana Design Manual* Figure 49-9D(50), 49-9D(60), 49-9D(70), 49-9D(80), 49-9D(90), 49-9D(100), or 49-9D(110) [english-units Figure 49-9D(30), 49-9D(40), 49-9D(45), 49-9D(50), 49-9D(55) , 49-9D(60), or 49-9D(65)], Median Barrier and Bridge Railing Test Level Selection, for the design speed shown in the figure designation.

The following procedure will apply to the determination of the appropriate Test Level.

1. Determine adjustment factors K_g and K_c from *Indiana Design Manual* (or english-units) Figure 49-9B, and K_s from Figure 49-9C.

2. Calculate the adjusted AADT by multiplying the construction year AADT (total for both directions) by the three adjustment factors, as shown below.

   $$\text{Adjusted AADT} = (\text{Construction year AADT})\ (K_g)\ (K_c)\ (K_s).$$

3. Determine the figure in the *Indiana Design Manual* (or english-units) 49-9D series which is appropriate for the design speed. If the design speed is 35 mph, a straight-line interpolation between Figures 49-9D(30) and 49-9D(40) should be used to determine the adjusted AADT range.

4. Locate the appropriate line in such figure under the Site Characteristics column.

5. Move across to the columns corresponding to the appropriate Highway Type.

6. Determine which of the three columns (TL-2, TL-4, or TL-5) includes the adjusted AADT value calculated in Step 2 to identify the appropriate Test Level.

Each side of a bridge should be checked against these criteria. This is especially important for a bridge on a horizontal curve. The highest Test Level warrant should be used for both sides of a structure.

See *Indiana Design Manual* Section 49-9.03 for example calculations on the selection of a TL-4 or TL-5 bridge railing.

For a minor bridge rehabilitation project which does not include bridge deck replacement or deck widening and the bridge currently has a crashworthy TL-4 bridge railing, the existing railing need not be upgraded to a TL-5 railing even though the warrants for the TL-5 railing are satisfied. If there is no significant history of truck accidents, the installation of the TL-5 bridge railing should be deferred until the time of deck replacement or deck widening. However, if truck accidents are a problem, consideration should be given to installing the TL-5 railing on the rehabilitation project along with countermeasures to reduce the truck-accident problem.

II. Bridge Railing Type Selection

A. INDOT Standard Railings

Once the Test Level has been determined, a bridge railing type should be selected to match the required Test Level and other considerations (e.g., aesthetics, owner preference).

Figure 05-05B, Bridge Railing Types, summarizes the Department-standardized bridge railing types for each Test Level.

Railing Designation	TS-1 *	PF-2	PS-2	TX **
Height Designation	Common	Pedestrian	Pedestrian	Pedestrian
Mounting Location	On bridge coping	Flush with bridge deck	Atop sidewalk of minimum 1.5 m (5 ft) width	Either atop sdwk. of 1.5 m (5 ft) min. width, or flush with bridge deck
Railing Element	Thrie-beam with steel posts	2 steel tubes with steel posts on concrete parapet	2 steel tubes with steel posts on concrete parapet	Concrete
Total Height	840 mm (33 in.)	1070 mm (42 in.)	1070 mm (42 in.)	1070 mm (42 in.)
Br. Rlg. Standard Drawings	n/a	706-BRPP-02, and -05, -06	706-BRPP-04 through -06	706-BRTX-01 through -04
Bridge Railing Transition	none	TPF-2	TPS-2	TTX
Br. Rlg. Trans. Standard Drawings	n/a	706-TTBP-03 and -04	706-TTBP-07 and -08	706-TTTX-01
Guardrail Transition	TGS-1	TGB	TGB	TGB
Gdrl. Trans. Standard Drawings	n/a	601-TTGB-01 through -05	601-TTGB-01 through -05	601-TTGB-01 through -05

* Bridge railing type **TS-1** may be used only on a local-public-agency collector or local road. Details for the bridge railing and transition are shown on **Recurring Plan Detail 706-R-140d.**

** Bridge railing type TX should be considered for an aesthetically-sensitive area.

BRIDGE RAILING TYPES
(Test Level 2)

Figure 05-05B

Railing Designation	none	TR ***	CF-1	PS-1	PF-1
Height Designation	Common	Common	Common	Pedestrian	Truck
Mounting Location	Flush with bridge deck	On existing concrete parapet	Flush with bridge deck	Atop sidewalk of minimum 1.5 m (5 ft) width	Flush with bridge deck
Railing Element	Concrete, shape F	Thrie beam with steel posts	2 steel tubes with steel posts on concrete curb	1 steel tube with steel posts on concrete parapet	1 steel tube with steel posts on concrete parapet
Total Height	840 mm (33 in.)	860 mm (34 in.)	900 mm (35 in.)	1070 mm (42 in.)	1270 mm (50 in.)
Br. Rlg. Standard Drawings	706-BCBR-01 through -04	706-TBRC-01, -02, -03; -TBRE-01; -TBRF-01, -02	706-BRTM-01 and -02	706-BRPP-03, and -05, -06	706-BRPP-01, and -05, -06
Bridge Railing Transition	TBC	none	none	TPS-1	TPF-1
Br. Rlg. Trans. Standard Drawings	706-CBRT-01 through -03	n/a	n/a	706-TTBP-05 and -06	706-TTBP-01 and -02
Guardrail Transition	TGB	TGB	TGT	TGB	TGB
Gdrl. Trans. Standard Drawings	601-TTGB-01 through -05	601-TTGB-01 through -05	601-TTGT-01 and -02	601-TTGB-01 through -05	601-TTGB-01 through -05

*** Bridge railing type TR should be used only to replace existing aluminum bridge railing where no other modifications to a bridge are to be made, either as a spot improvement or within the limits of a 3R or 4R project.

BRIDGE RAILING TYPES
(Test Level 4)

Figure 05-05B (Cont'd.)

Railing Designation	none	TF-2
Height Designation	Truck	Truck
Mounting Location	Flush with bridge deck	Flush with bridge deck
Railing Element	Concrete, shape F	2 steel tubes with steel posts on concrete parapet
Total Height	1145 mm (45 in.)	1270 mm (50 in.)
Br. Rlg. Standard Drawings	706-BCBR-02, -03, and -04	706-BCTF-01 through -10
Bridge Railing Transition	TBT	PBT
Br. Rlg. Trans. Standard Drawings	706-CBRT-01, through -03	706-TPBT-01 through -09
Guardrail Transition	TGB	TGB
Gdrl. Trans. Standard Drawings	601-TTGB-01 through -05	601-TTGB-01 through -05

BRIDGE RAILING TYPES
(Test Level 5)

Figure 05-05B (Cont'd.)

Figure 05-05C, Bridge Railing Pay Items, summarizes the required pay item names and pay units for each Department-standardized bridge railing type for each Test Level.

Railing Desig-nation	Railing		Bridge Railing Transition		Guardrail Transition	
	Pay Items	Pay Units	Pay Items	Pay Units	Pay Items	Pay Units
TS-1	Railing, TS-1	m (LFT)	none	n/a	Guardrail Transition, TGS-1	EACH
PF-2	Railing, PF-2 Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m (LFT) m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TPF-2	EACH	Guardrail Transition, TGB	EACH
PS-2	Railing, PS-2 Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m (LFT) m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TPS-2	EACH	Guardrail Transition, TGB	EACH
TX	Railing, TX Reinforcing Steel, Epoxy Coated	m (LFT) kg (LBS)	Concrete Bridge Railing Transition, TTX	EACH	Guardrail Transition, TGB	EACH

Test Level 2 Railings

Shape F conc.	Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TBC	EACH	Guardrail Transition, TGB	EACH
TR	Railing, TR	m (LFT)	none	n/a	Guardrail Transition, TGB	EACH
CF-1	Railing, CF-1	m (LFT)	none	n/a	Guardrail Transition, TGT	EACH
PS-1	Railing, PS-1 Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m (LFT) m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TPS-1	EACH	Guardrail Transition, TGB	EACH
PF-1	Railing, PF-1 Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m (LFT) m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TPF-1	EACH	Guardrail Transition, TGB	EACH

Test Level 4 Railings

Shape F conc.	Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, TBT	EACH	Guardrail Transition, TGB	EACH
TF-2	Railing, TF-2 Railing, Concrete, C Reinforcing Steel, Epoxy Coated	m (LFT) m^3 (CYS) kg (LBS)	Concrete Bridge Railing Transition, PBT	EACH	Guardrail Transition, TGB	EACH

Test Level 5 Railings

BRIDGE RAILING PAY ITEMS

Figure 05-05C

B. FHWA-Approved Non-INDOT-Standard Railings

There are other bridge railings which have passed NCHRP *350* crash tests for specified Test Levels, in addition to those which the Department has standardized. These are identified on the FHWA's website, http://safety.fhwa.dot.gov/roadway-dept/road_hardware/bridgerailings.htm. If one of these devices is desired to be used for a specific project, the required documentation to be downloaded from the website and provided is as follows:

1. an acceptance letter from the FHWA that approves the device for use; and

2. complete details for the device as successfully crash tested.

The device may be modified for specific-project use. However, the shape, strength, and performance requirements cannot be changed. If the device is to be modified, the additional required documentation to be provided is as follows:

1. complete details showing the modifications; and

2. calculations showing that the modified version still meets the strength and performance requirements of the crash-tested version.

The appropriate transition or end treatment must be determined. This may be done by further investigating the bridge railing details. Such details should be provided, along with documentation that the transition or end treatment is appropriate for the bridge railing. If an appropriate transition or end treatment cannot be found, the bridge railing cannot be used.

C. Considerations if Sidewalk Present

Including a sidewalk on a bridge may impact the selection and/or location of the bridge railing. The potential problem is that, once a vehicle strikes a curb, it may become airborne. Depending upon the lateral offset of the bridge railing, the vehicle may impact the railing while airborne and thus, may interfere with the proper vehicle/bridge railing interaction.

The following will apply to the selection and location of a bridge railing in combination with a sidewalk.

1. Design Speed of 70 km/h (45 mph) or Lower. Only a railing shown to be crashworthy in the presence of a sidewalk may be used. The bridge railing type may be selected based on the Test Level required at the site as described above, or a vertical concrete wall of the appropriate height may be provided at the back of the sidewalk. The Test Level of such wall should match that of a concrete shape F bridge railing.

2. Design Speed of 80 km/h (50 mph) or Higher. The bridge railing cannot be placed at the coping side of the sidewalk, therefore it must be placed between the roadway and the sidewalk. A pedestrian- or bicycle railing should then be placed at the coping side of the sidewalk as described below. The height of the vehicular bridge railing between the roadway and the sidewalk must meet or exceed the minimum height requirement of a pedestrian railing, 1070 mm (42 in.), or a bicycle railing, 1370 mm (54 in.), whichever applies. Where the vehicular bridge railing is placed between the roadway and the sidewalk, the sidewalk need not be raised; i.e., the roadway surface and sidewalk surface may be at the same elevation. However, the sidewalk drainage pattern should be reviewed. The guardrail transition and bridge railing transition should be connected to the pedestrian railing. An impact attenuator type R1 should be connected to the bridge railing.

III. Bridge Railing Design Details

A. Superelevated Bridge Deck

INDOT *Standard Drawings* 706-BCBR-03 and -04 illustrate the orientation of concrete shape F bridge railing with the bridge deck surface for a bridge on a superelevated roadway section.

B. Barrier Delineators

Barrier delineators are to be placed on all bridge railings. However, barrier delineators are not to be placed on bridge railings at the coping sides of sidewalks. The location of the delineators along the bridge railing should be as described in the INDOT *Standard Specifications*. Barrier delineators should be placed on the roadway faces of bridge railing transitions.

IV. Bridge Railing Transitions

Steel-element roadside barriers deflect upon impact, but rigid bridge railings normally will not. Therefore, where a steel-element roadside barrier approaches a rigid bridge railing, a transition is necessary to gradually strengthen the steel-element roadside barrier as it approaches and connects to the bridge railing. The following will apply to these transitions.

A. Type

The preferred transition for each bridge railing type is shown in Figure 05-05B. Most systems include both a guardrail transition and a bridge railing transition. The details are shown in the INDOT *Standard Drawings* identified in Figure 05-05B.

The transitions are typically used at all locations, except where an intersecting road or driveway prevents the placement of a proper design. To use the bridge railing transition listed, there must be space to place at least 7.62 m (25 ft) of roadside barrier between a curved W-beam guardrail connector terminal system or curved W-beam guardrail system and the beginning of a guardrail transition type TGB.

Bridge railing transition type WBC is not identified in Figure 05-05B. It may be used with concrete bridge railing shape F, common height, only where the proximity of an intersecting road or driveway prevents the proper installation of the preferred transition. Where at least one bridge railing transition type WBC is required, such transition should be used for all bridge railing ends.

B. Location

The following will apply to the location of bridge railing transitions.

1. Reinforced Concrete Bridge Approach (RCBA). The ideal treatment is to locate a bridge railing transition along the RCBA. This will keep the deck drainage not collected in the deck drains from flowing down the spill slopes at the bridge corners, which may cause erosion at the end bents. Placing the transition on the RCBA will require moving the connection between the bridge railing transition and the guardrail transition a sufficient distance from the wing to allow placement of the posts required with the transition.

2. Bridge Corners. Transitions should be used at all bridge corners for all bridge railing types, including the trailing ends of bridge railings on a one-way roadway such as a ramp or one roadway of a divided highway.

3. Bridge Deck. If it is necessary to locate the transition on the bridge deck, the wings must be extended laterally a sufficient distance to provide a minimum clearance of 150 mm (6 in.) between the roadside face of the wing and the backs of the guardrail transition posts.

4. Intersecting Roads or Drives. The presence of intersecting roads or drives close to the bridge may complicate the location of the transition. Where practical, the intersecting road or drive should be relocated to allow placement of the bridge railing transition on the RCBA. Where this is not practical, the consideration of the bridge railing transition should be determined in the order of preference as follows:

a. it should be placed on the bridge deck if the structure has integral or semi-integral end bents;

b. a modified version of the bridge railing transition that can be used with guardrail transition type WGB should be placed on the RCBA;

c. a modified version of the bridge railing transition that can be used with guardrail transition type WGB should be placed on the bridge deck if the structure has integral end bents;

d. an impact attenuator should be used at the end of the bridge railing; or

e. since standard details for modified versions of bridge railing transitions that can be used with the guardrail transition type WGB are not available, details of a modified version of the appropriate concrete bridge railing transition should be included in the plans if an intersecting drive or public road approach cannot be relocated away from the end of the structure.

5. Expansion Joints. The bridge railing transition cannot be located on the bridge deck if a deck expansion joint is located between the bridge deck and the mudwall.

6. Alternative Locations. In a situation with severe space restrictions, transition locations and/or design modifications which do not comply with the above criteria may be necessary. These alternative treatments require approval by the Design Division Chief.

V. Pedestrian Railings

If a sidewalk is to be placed on a bridge, and the design speed is 80 km/h (50 mph) or higher, a bridge railing should be used to separate vehicular traffic from pedestrians, and a pedestrian railing should be placed on the outside edge of the sidewalk.

If the design speed is 70 km/h (45 mph) or lower, the need for protection of pedestrians by means of a combination vehicular bridge railing/pedestrian railing will be considered on a site-by-site basis. Additional considerations to be made are as follows:

1. design speed;
2. vehicular-traffic volumes;
2. pedestrian-traffic volumes;
4. accident history;
5. geometric impacts (e.g., sight distance);

6. practicality of providing proper end treatments;
7. construction costs; and
8. local preference.

VI. Bicycle Railings

If bicyclists are permitted to use a bridge, a bicycle railing may be warranted. The following will apply.

A. Bicycle Path

This is defined as a bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Each bridge which is a part of a bicycle path will require bicycle railings of 1370 mm (54 in.) height.

B. Other Facilities

The need for combination vehicular bridge railing/bicycle railing to protect bicyclists will be considered on a site-by-site basis. Additional considerations to be made are as follows:

1. motor-vehicular traffic design speed;
2. motor-vehicular traffic volumes;
3. bicycle traffic volumes;
4. accident history;
5. geometric impacts (e.g., sight distance);
6. practicality of providing proper end treatments;
7. construction costs; and
8. local preference.

alu
Attachments

[F:\Des\Signed\0505-ta.doc]